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None

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UK CL (Edition J) G1U UBF, H4L
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(54) Spectrum analysis in a communications system

(57) In a communications ESM system wherein an incoming signal is converted to an intermediate frequency and then Fourier analysed (as in Fig. 2 not shown), the frequency spectrum (Fig. 3) for energy values above a detection threshold is analysed to determine whether observed peaks are merely side bands of other peaks, e.g. P and Q relative to A in Fig. 3, or whether they are independent signals, e.g. signals (ii) and (iii). In use, the largest peak (A) is identified (20) and the frequency difference (v) between edge values (B,C) on either side of a below-threshold point is determined (22, 24, 26, 30) and is compared (32) with a pre-set value. If the difference (V) is greater than the pre-set value a new signal is assumed to start at edge value C. If it is not, a decision as regards whether a new signal is starting is made depending on the ratio of the peaks P:Q (as determined at 36, 38, 40).

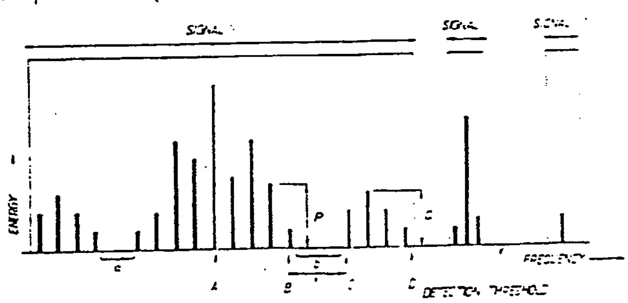

Fig3

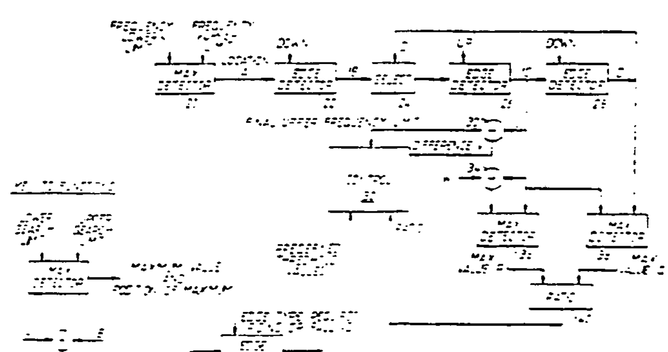

Fig 4

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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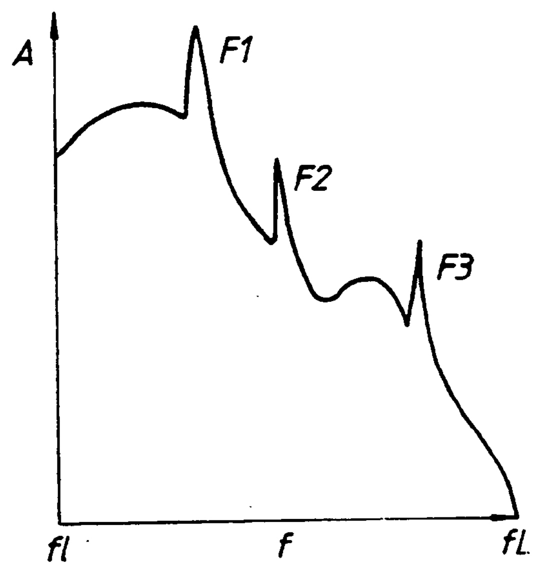
A
F1
F2
F3
fl
f
fL

Fig.1.

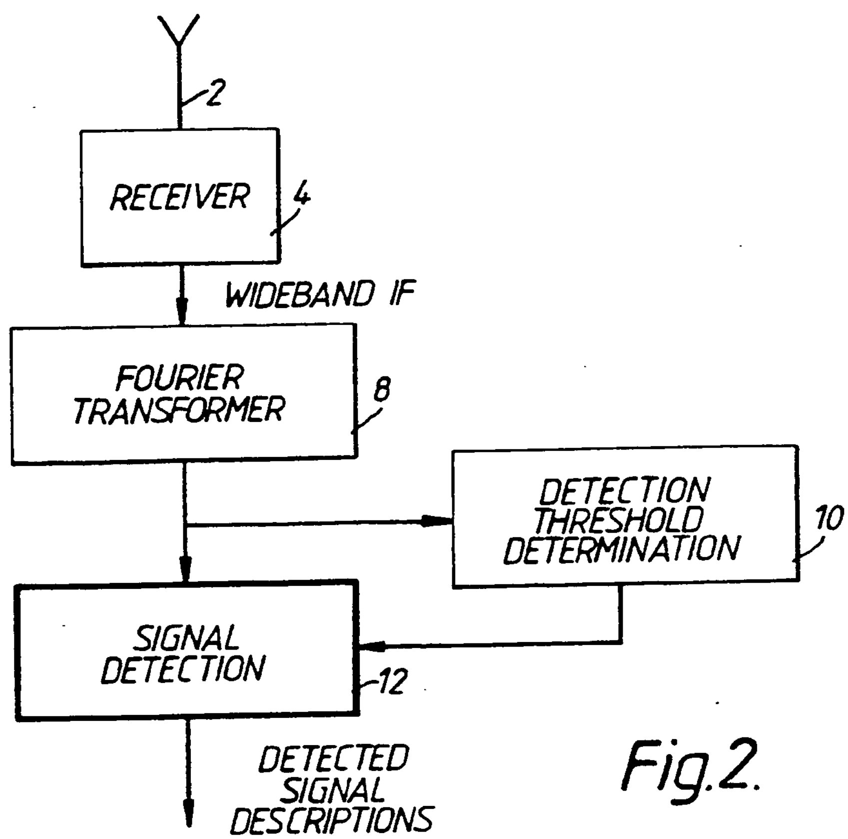
2
RECEIVER
4
WIDEBAND IF
FOURIER TRANSFORMER
8
DETECTION THRESHOLD DETERMINATION
10
SIGNAL DETECTION
12
DETECTED SIGNAL DESCRIPTIONS

Fig.2.

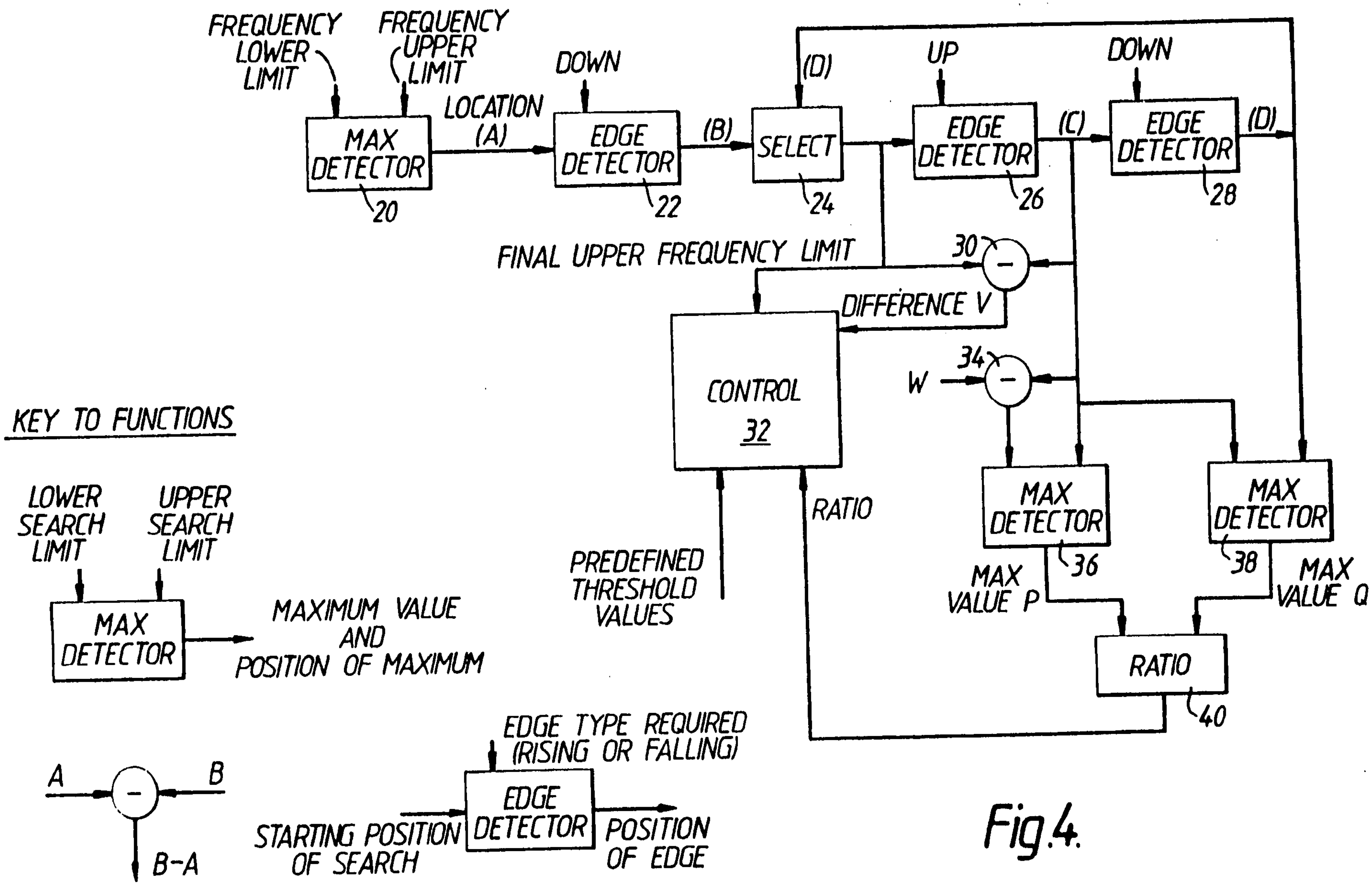
FREQUENCY LOWER LIMIT
FREQUENCY UPPER LIMIT
MAX DETECTOR
20
LOCATION (A)
DOWN
EDGE DETECTOR
22
(B)
SELECT
24
(D)
UP
EDGE DETECTOR
26
(C)
DOWN
EDGE DETECTOR
28
(D)
FINAL UPPER FREQUENCY LIMIT
30
DIFFERENCE V
CONTROL
32
34
W
MAX DETECTOR
36
MAX DETECTOR
38
MAX VALUE P
MAX VALUE Q
RATIO
40
RATIO
PREDEFINED THRESHOLD VALUES
KEY TO FUNCTIONS
LOWER SEARCH LIMIT
UPPER SEARCH LIMIT
MAX DETECTOR
MAXIMUM VALUE AND POSITION OF MAXIMUM
A
B
B-A
EDGE TYPE REQUIRED (RISING OR FALLING)
EDGE DETECTOR
STARTING POSITION OF SEARCH
POSITION OF EDGE

Fig.4.

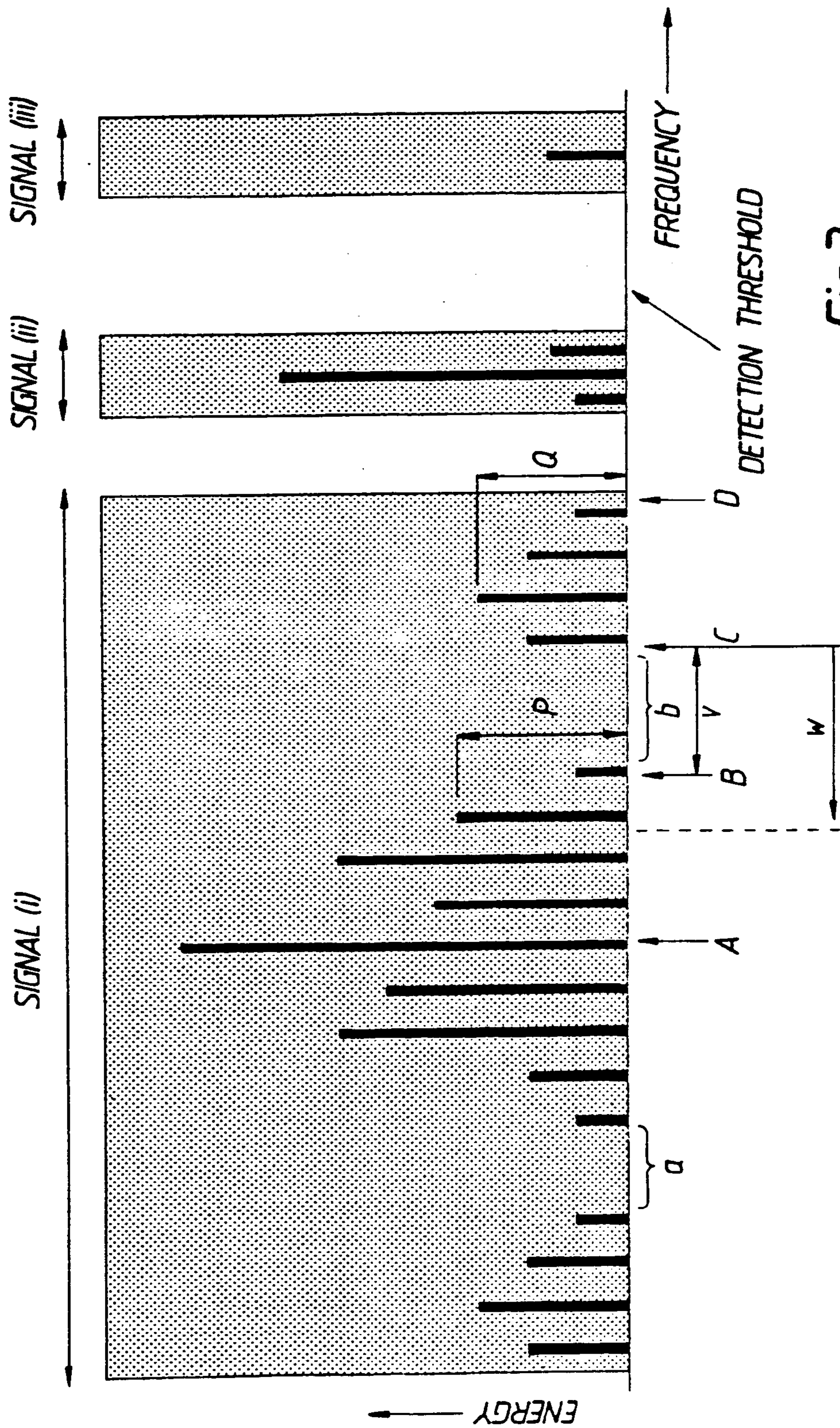
SIGNAL (i)
SIGNAL (ii)
SIGNAL (iii)
FREQUENCY
DETECTION THRESHOLD
ENERGY
A
B
C
D
a
b
P
Q
V
W

Fig.3.

METHOD FOR DETECTING SIGNALS IN A COMMUNICATIONS ESM SYSTEM

The present invention relates to a method for detecting signals in a communications ESM system.

ESM is an abbreviation for Electronic Support Measures which are commonly used in electronic warfare systems. Such electronic warfare systems commonly involve detecting signals over a wide frequency spectrum and interpreting these signals by means of computer databases and other computer techniques, and then taking appropriate counter measures for example jamming an enemy's communication lines.

One problem which arises is to accurately detect all signals within a wide frequency band for example HF up to EHF and to keep track of all detected signals. Commonly a bank of passive antenna are provided individually connected to receivers and detection apparatus, each receiver allocated to a different bandwidth. Within each band allocated to a particular receiver, is necessary to analyse all incoming signals. A common form of received signal for a frequency band of interest is shown in Figure 1 where it can be seen the noise "non-white", i.e. non-Gaussian, possibly due to interference from adjacent transmitting equipment having a peak value at the low end of the frequency band thereafter decreasing, rising to a subsidiary peak at a mid-point in the spectrum and then decreasing rapidly to the upper frequency end of the spectrum. Signals F1, F2 and F3 may be superimposed on this noise. Non-white noise is frequently due to interference from adjacent transmitting equipment and inherent characteristics of the receiving equipment.

Figure 2 shows a typical receiver for an ESM system as comprising an antenna 2, a receiver 4, and the output from the receiver 4 being a wide band IF signal, say 200KHz or several MHz. Normally receiver 4 is arranged to sweep across the entire frequency band so that the output IF signal sweeps across the band at a repetition rate determined by the receiver. The IF signal is analysed in a fourier transformer circuit 8 which identifies all frequencies within the wide band IF signal together with their amplitudes. The transformer 8 thus provides a spectrum of the IF signal and from this spectrum a threshold value is determined in circuit 10, so that any spectral energy having a value which is below the threshold is deemed not to be of interest. The threshold value is provided to a signal detection unit 12 which compare the threshold with the spectrum provided by the fourier transformer 8 and from this comparison determines signals which appear to be of interest.

One method of detection which has been used in the past to locate signals in the presence of noise is known as a peak picking method wherein each peak detected above a predetermined signal threshold is assumed to represent a separate signal. The problem with this technique is that side band signals tend to be classified incorrectly as separate signals and hence too many detected signals are identified.

Another method of signal detection is to divide the frequency band of interest into predetermined signal frequency "channels". If the energy within the channel is above a predetermined threshold barrier, then that channel is classified as containing a signal. The problem with this method is that signals may be spread across two or more adjacent channels, and hence erroneous signal detections are made. This may be due to signal centre frequencies not being aligned with the channel frequencies, resulting in energy being spread over more than one channel, or may be due to a signal having a number of side bands which spread into adjacent channels.

It is therefore an object of the present invention to provide a method of analysing received signals in a communications ESM system which accurately locates and identifies received signals and wherein the risk of false detection is reduced.

The present invention provides a communications ESM system comprising;

an antenna and receiver responsive to a predetermined frequency band, the receiver including local oscillator means for producing a local oscillator signal which sweeps across the frequency band in order to produce an IF signal which sweeps across the frequency band in recurrent cycles of operation;

fourier transform means for spectrally analysing the IF signal to determine the frequencies present in the IF signal for each sweep of the IF signal across the frequency bands;

means for determining a threshold value from the spectrally analysed IF signal so that for energy levels below the threshold, such energy values are not assumed to represent signals of interest;

signal detection means for comparing the spectrally analysed signals from the fourier transform means with the threshold value, said signal detection means including;

means for identifying all peaks in each spectrum above said threshold value, means for measuring the difference in frequency between adjacent peaks and comparing adjacent peaks in terms of their relative amplitude and the frequency difference therebetween to determine whether one peak is a side band of the other; and,

providing output signal descriptions to storage means of those peak signals which are identified to be separate signals.

Thus in accordance with the invention means are provided for distinguishing between side band signals and actual signals in a spectrum of received signals, which means does not suffer from the disadvantages of the method used previously. In particular it is not necessary to set predetermined frequency channels and analyse signals within each channel, it does not falsely identify side band signals as separate signals to be analysed. Further the method may be simply implemented requiring a minimum of processing and is suitable for use with high speed signal detection systems.

A preferred embodiment of the invention will now be described with reference to the accompanying drawings, wherein:-

Figure 1 is a schematic view of a signal received in a communications ESM system in the presence of non-white noise;

Figure 2 is a schematic diagram of a communications ESM system for use in the present invention;

Figure 3 is a schematic view of a spectrum of an incoming signal which has been analysed so as to identify signal peaks above the threshold value; and,

Figure 4 is a block diagram of a preferred embodiment of the signal detecting apparatus according to the present invention.

Figures 3 and 4 are used to describe the method.

Figure 3 illustrates an example scenario; it shows a detection threshold and the spectral energy above threshold. Three signals are shown (i), (ii), (iii), one (signal (i)) having sidebands which temporarily fall below the detection threshold in regions a, b. It will be noted the spectral energy estimates have an equal frequency spacing, this being determined by the method of spectral analysis, involving fourier analysis of fixed width frequency channels. The letters v, w, A, B, C, D, P, Q refer to parts of the waveform at different processing stages in the system of figure 4.

Figure 4 provides an example circuit diagram to implement the method. The diagram shows only one side of the clustering circuitry for reasons of clarity. Two such circuits are generally required. or a modification to the circuit shown will enable it to perform the total function.

The hardware described by Figure 4 contains a number of maximum locators and edge locators which perform the following tasks:

(i) A max detector 20 locates the maximum value (and the ordinate of the maximum value) of the above detection threshold energy within the range specified by the upper and lower frequency limits. Detector 20 is coupled to edge detector 22, a select circuit 24, and edge detectors 26, 28.

(ii) An edge detector locates the position (ordinate) of the edges of the above detection threshold energy. The particular edge located (rising or falling) is determined by the control input (up or down). The starting position for searching for an edge is determined by the input signal to the detector (see Figure 4).

The above circuit functions may be implemented with counter and comparator logic devices.

Operation of the method (and apparatus) is now described with reference to Figure 3 and 4.

Given the "spectrum" of detected data and the upper and lower frequency limits of interest v, w (predefined parameters) (Figure 4), the location of largest signal peak (A) is identified by max detector 20.

The right side (highest frequency) edge of the above detection threshold data is located ((B) in Figure 3) by an edge detector 22 which starts searching from position (A) as shown in Figure 4. The selector 24 (Figure 4) is initially set to select the (B) input. The rising edge of the next energy segment (C) is located in detector 26.

The frequency difference (v) between the edge (B) and the rising edge of the next energy segment ((C) in Figure 3) is computed in a subtractor 30. The difference v is applied to a control unit 32.

If the frequency difference ((v) in Figure 3) is greater than a predefined threshold value stated in unit 32, then clustering halts and the frequency (B) is defined as the signal upper frequency of the band of signals comprising signal (i). This frequency is fed to the control unit 32 via the selector unit 24 for storage.

If the frequency difference (v) is below the predefined threshold, then the next segment is associated with the signal peak (A) if the following conditions are satisfied:

(i) A "window" of frequency width w is specified as shown in Figure 2 by applying a fixed signal w to a subtractor unit 34 where it is compared with the frequency signal from edge detector 26. The peak amplitude value (P) (Figure 2) within this window is located by a max detector 36 (Figure 4).

(ii) The peak amplitude value of the cluster under consideration (Q) (Figure 2) is located by a max detector (38) (Figure 4).

(iii) The values P and Q are compared in a ratio device 40, and if the value of Q/P does not exceed a predefined threshold, then the next cluster is associated with the signal peak, else the upper frequency (B) is defined as the signal upper frequency of signal (i) and a new signal begins thereafter.

This condition ensures that energy is clustered only if the peak power of the additional energy is in line with that expected, assuming the energy is a sideband of the signal under consideration. The ratio is determined by consideration of the spectrum of aims and from modulated signals in general terms.

If clustering has not halted due to the finding of an upper frequency limit, then clustering continues in a similar manner. The control function sets the selector 24 (Figure 4) to select the alternative input ((D) in this case) to selector 24, and the process continues by working upwards in frequency.

When clustering has halted due to the finding of an upper frequency limit, then the output of the selector function is the upper frequency limit for the signal. A similar process is followed for clustering on the low frequency side of the peak cluster (A) to provide the lower frequency limit of the signal.

When all clustering for peak (A) has halted, then the clustered data represent a single detected signal. Data from this signal is removed from the spectral data and the whole process ((a) to (g) above) is repeated until all above threshold energy has been allocated to a signal.

Figure 3 illustrates an example situation where three signals are detected. Signal (ii) is not clustered into signal (i) since the peak energy does not fall in line with the expected sideband power trend of signal (i) (See condition (e) above). Signal (iii) is not clustered into signal (ii) since the frequency difference (condition (d) above) between the edges of each signal exceeds the predetermined threshold.

CLAIMS

1. A communications ESM system comprising;

an antenna and receiver responsive to a predetermined frequency band, the receiver including local oscillator means for producing a local oscillator signal which sweeps across the frequency band in order to produce an IF signal which sweeps across the frequency band in recurrent cycles of operation;

fourier transform means for spectrally analysing the IF signal to determine the frequencies present in the IF signal for each sweep of the IF signal across the frequency bands;

means for determining a threshold value from the spectrally analysed IF signal so that for energy levels below the threshold, such energy values are not assumed to represent signals of interest;

signal detection means for comparing the spectrally analysed signals from the fourier transform means with the threshold value, said signal detection means including;

means for identifying all peaks in each spectrum above said threshold value, means for measuring the difference in frequency between adjacent peaks and comparing adjacent peaks in terms of their relative amplitude and the frequency difference therebetween to determine whether one peak is a side band of the other; and, providing output signal descriptions to storage means of those peak signals which are identified to be separate signals.

2. A system as claimed in claim 1, wherein in said comparison of adjacent peaks, the largest peak in the spectrum is located, and the

adjacent peaks are compared with the largest peak, until a region is located in which no peak exists, this region being taken as bounding the edge of a side band.

3. A system as claimed in claim 2 wherein having determined the edge of a side band, the peak next adjacent the sideband is compared in frequency with the edge of the sideband, and if the difference is greater than a predetermined threshold value, the side band edge is confirmed as such.

4. A system as claimed in claim 3 wherein the difference is less than said predetermined threshold value, a window is defined of a fixed frequency width extending from said next adjacent peak, and the peak within said side band and within said window having the largest value is determined.

5. A system as claimed in claim 4 wherein signals adjacent to said next adjacent peak are analysed and if adjudged to form a further sideband, the largest peak within the further side band is determined, and compared in amplitude with said largest value peak and wherein if the ratio of amplitudes does not exceed a predetermined threshold, then the further side band is determined to form part of the first mentioned side band.

6. A communications ESM system substantially as described with reference to the accompanying drawings.

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